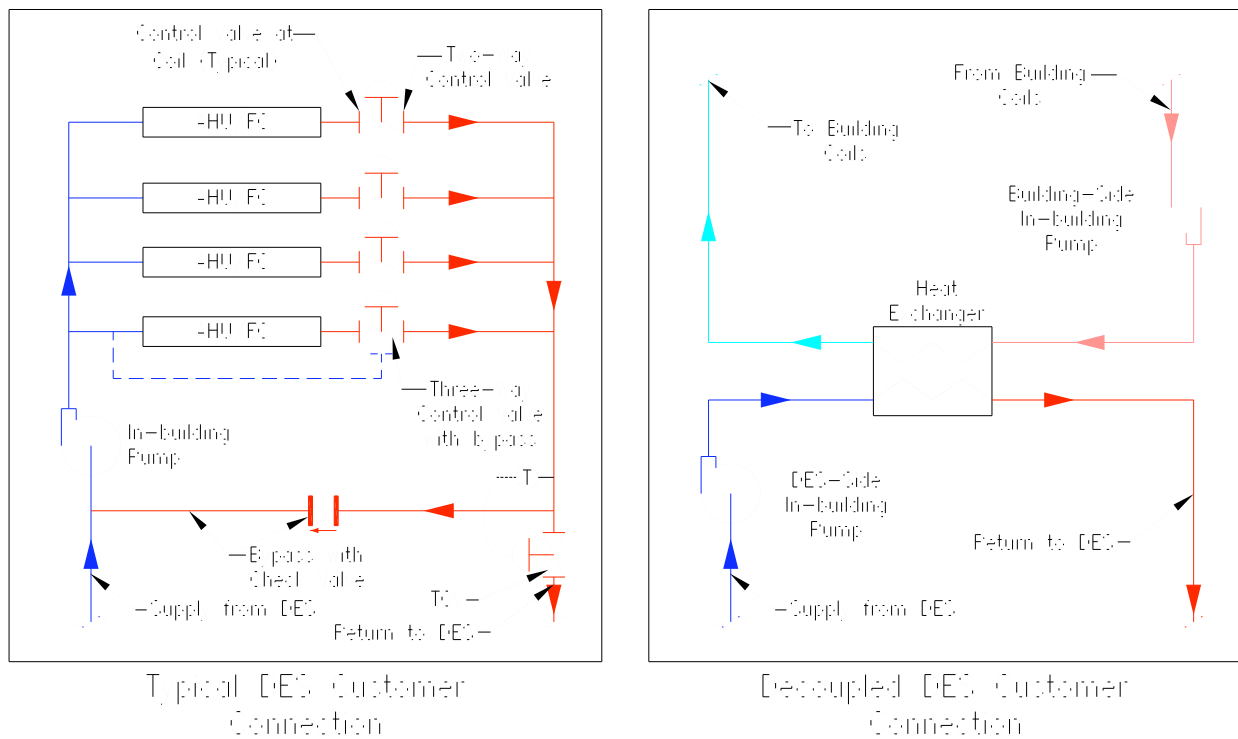


## Chilled Water System Control for Buildings Connected to MNDES

Kevin L. Jacobs, P.E.

Currently, 38 buildings are connected to the Metro-Nashville District Energy System (DES) utilizing chilled water produced at the Energy Generating Facility (EGF). Most buildings are connected in a similar manner with a few exceptions. The manner in which the buildings are connected is very similar to that of district cooling systems around the world. However, there are a number of different configurations that are also used depending on the parameters and requirements of both the building and the district system. Many articles have been published in various engineering journals regarding the pros and cons of each connection type.

Currently, six of the buildings are connected via a plate-and-frame heat exchanger. These customers are referred to as “decoupled” since the chilled water from the DES does not circulate throughout the building but is separated from the internal building cooling system with the heat exchanger. The remaining buildings typically use a temperature control valve (TCV) in the chilled water return line in conjunction with a bypass line connecting the supply and return upstream of the TCV and the building circulating pump(s). At least one chilled water pump is utilized in each building to force circulation throughout the in-building cooling system. A schematic is shown in Figure 1 of the two basic connections types for DES customers.



**Figure 1. Typical DES Customer Connection Types**

### Typical Connections

The majority of DES customers have a connection similar to the one shown at the left of Figure 1. The in-building pumps are typically constant speed and circulate chilled water through the building cooling system (air handlers and fan coils; AHU/FC). A control valve, either two-way or three-way, regulates the flow rate through the coil based on the airside temperature of the unit.

The temperature control valve in the return line throttles to maintain the building return water set-point. When the TCV is 100% open, all of the building return water flows back to the DES. When the TCV is throttling, a portion of the building return water is re-circulated and blends with the supply water from DES to produce a slightly elevated supply temperature. A higher supply temperature typically results in a higher return temperature. Therefore, throttling the TCV and re-circulating a portion of the return water can maintain the return water set-point.

This configuration causes the building flow rate to remain essentially constant with changing loads, although the DES flow rate will vary depending upon the amount of re-circulation that is required to satisfy the set-point temperature. Also, the supply temperature to the building coils varies with changing loads. At high loads with no re-circulation, the supply temperature to the coils will be equal to the supply from DES (approximately 42°F). However under low loads, most of the chilled water may be re-circulated, causing the water temperature to the coils to be much higher than 42°F. Although higher water temperatures typically result in slightly higher air-side temperatures, this scenario typically does not create any cooling issues since high re-circulation rates usually only occur during non-cooling periods (i.e., winter months).

With a near constant building-side flow rate, the return temperature set-point may not be achieved during low load periods (such as the winter months). With a relatively low load, an insufficient amount chilled water may be re-circulated or the coils may lack the ability to heat the chilled water to the return temperature set-point. In either case, the chilled water return temperature will not reach the set-point value and may result in an average monthly return temperature less than the return temperature set-point. Whenever this situation occurs, the customer is charged a Thermal Inefficiency Fuel Surcharge (TIFS).

Since the pumps in this configuration are typically constant speed, the electrical energy requirements of the pumps does not significantly change throughout the year or with building cooling load. The pumps generally operate at the same level year-round, therefore, the monthly consumption of electrical energy is essentially constant – regardless of cooling load.

A variation on this connection type is to install a variable speed drive (VFD) on the building's circulation pump. The control system for the VFD can be configured to reduce the flow rate through the building to maintain a return water set-point. In this case, the TCV and bypass lines are not required or if installed, will operate in the closed position. This configuration will result in a reduction in electrical energy used by the pump since the pump speed will decrease as the load decreases.

However, VFDs cannot be economically justified for all customers. Some customers have relatively high winter cooling loads, thus the energy savings may not be significant during non-cooling periods. Also, if three-way control valves are used at the coils, the valves will have to be replaced or the bypass lines plugged in order to successfully reduce the building flow rate whenever the cooling load is less than design. The modifications that may be required for these control valves can be capital intensive, thus further reducing the economic benefit the energy savings may produce.

## **Decoupled Connections**

The decoupled customers are typically those with significantly tall buildings. By decoupling a building from the distribution system, the effect of the elevation head imposed by the relative

height of the building's coils is eliminated. This configuration reduces the overall hydraulic impact that any one building can impose on the system, thus reducing the back-pressure that other customers may experience due to the elevation head of a few buildings.

For many of the decoupled customers, a control system monitors and varies the speed of the DES-side pumps and the building-side pumps to regulate the leaving return water temperature to DES and to ensure that the building coils are receiving the appropriate temperature for the given load. The re-circulation aspect of the TCV and bypass in the typical connection is unnecessary with a variable speed drive at the DES-side pump. In fact, the re-circulation of the chilled water return with a heat exchanger may result in higher than desired building-side temperatures. These relatively high building-side temperatures could potentially result in space conditioning problems under certain load conditions.

The use of VFDs provides a number of benefits for this particular connection type. Under low load conditions, the VFD reduces the pump speed further reducing the electrical energy consumption by the pumps. The return water temperature control is accomplished by varying the pump speed, which, in turn, varies the flow rate of chilled water through the heat exchanger. This method of temperature control has proven quite effective in maintaining the return temperature set-point over a wide range of building loads. However, at extremely low loads, the return temperature begins to fall due to the inability to completely shut-down the building-side pumps.

With most plate and frame heat exchangers, the flow rate through each side of the heat exchanger needs to be approximately equal, regardless of the load, in order to maintain the appropriate approach temperature. The approach temperature is the difference between the DES supply temperature and the building supply temperature. Whenever the building-side flow rate is considerably higher than the DES-side flow rate, the approach temperature will be high, resulting in elevated building-side temperatures. Conversely, when the DES-side flow rate is high, the approach temperature may be relatively low. A low approach temperature does not necessarily result in building-side cooling problems, but does require more pumping energy than necessary on the DES-side pumps.

With some decoupled customers, the control system has the ability to shut-down the DES-side pumps at low loads. For these customers, a bypass is installed around the DES-side pump and a temperature control valve is installed in the DES return line. When the pump is shut-down, water continues to flow through the DES-side of the heat exchanger due to the DES pressure difference between the supply and return lines. The return water set-point is maintained by throttling the temperature control valve in the return line to reduce the DES-side flow rate, thus maintaining the set-point return temperature. These particular customers benefit during the winter months by having fewer pumping hours per month, thus reducing the electrical energy needs of the building.

## **Other Items**

An article was written in the November 2007 issue of ASHRAE Journal by James B. Rishel, P.E. entitled, "Connecting Buildings to Central Chilled Water Plants." Mr. Rishel provides an excellent explanation of the various connection configurations possible for connecting a building to a district cooling system, such as DES. However, the bulk of his explanations relate to the design of new buildings connections and not existing buildings. In order to accomplish his

recommendations for building connections for many of the existing DES customers, the control valves and cooling coils in the buildings would have to be replaced. Typically, such a renovation would be cost-prohibitive and very disruptive to the daily operation of many of the customers, but could result in energy savings and potentially improved comfort.

## **Avoiding TIFS**

TIFS are incurred whenever the average monthly return temperature is less than the contract value. For most customers, the contract return temperature is used as the set-point for the temperature control. Low average monthly return temperatures are caused by the inability of the coils to add enough heat to the chilled water to satisfy the return temperature set-point. The use of constant speed pumps, three-way control valves at coils and end-of-run pressure control valves results in a near constant building-side flow rate, which will inevitably result in a low water-side temperature difference during low load periods.

Another cause of TIFS is due to poor heat transfer at the coils. Dirty air filters and coils (inside and out) reduce the flow of air across the coils, thus reducing the overall heat transfer and resulting in a reduced return water temperature. Occasionally, make-up air or economizer cycle dampers become stuck allowing too much outside air into the units during the winter months, which will also reduce the return water temperature.

Some customers may not be able to completely avoid TIFS regardless of what actions they take to prevent them. However, maintaining clean coils, on the air-side as well as the water-side, and clean air filters can improve the heat transfer across the coils and raise the return water temperature. If possible, three-way valves can be replaced with two-way valves that throttle the water flow through a particular coil to help maximize the return water temperature. Two-way valves can also shut-down the chilled water flow completely during low load periods. Two-way valves work best in conjunction with VFDs to produce a variable flow system throughout the year. It may even prove useful to manually isolate coils during non-cooling periods or to isolate the entire building. In such cases, winterization of the coils may be necessary. Decoupled customers utilizing the appropriate control system seldom have TIFS, but the infrequency of their occurrence has more to do with their use of VFDs and the appropriate control system than with the use of a heat exchanger.

## **Summary**

The majority of DES chilled water customers is connected directly to the system and utilizes a temperature control valve and bypass line to maintain the return temperature set-point. A few customers utilize a decoupled system in which a heat exchanger is used to separate the DES chilled water system and the in-building cooling system. Decoupled customers are typically those with relatively tall buildings since decoupling a building eliminates the hydraulic impact of the building's elevation.

Most customers utilize constant speed pumps and maintain a near constant building-side flow rate regardless of cooling load. This scenario may make the operation of the cooling system simple, but it does not maximize energy efficiency and may result in frequent TIFS. The use of variable speed drives (VFDs) typically result in an energy savings and a reduction in the magnitude or frequency of TIFS. Additional regular maintenance, such as maintaining clean coils and air filters, can also help reduce TIFS.

There are a number of possible customer connection possibilities and potentially a number of improvements that could be made to your existing in-building cooling system that could result in an energy savings. An engineering evaluation is required to determine what those changes may be and their economic benefit to your building.